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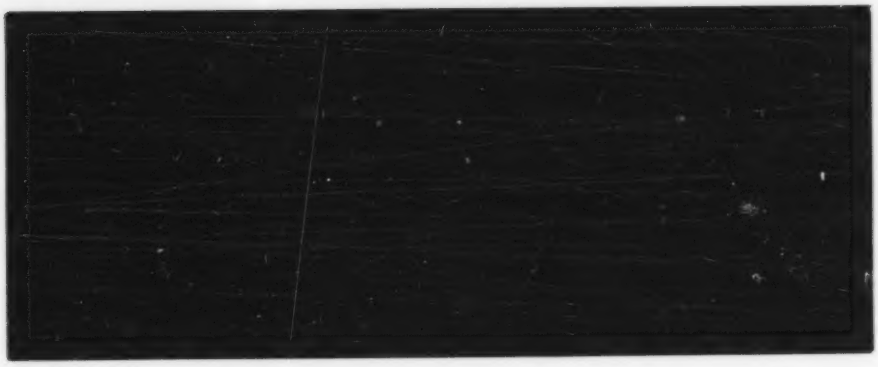

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Final Report

ERDA 1.2-12

Where Does Ascochyta Blight of Lentil Come From?

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Where does Ascochyta Blight of Lentil Come From?

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Final Report, 1989–90
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(a) EXECUTIVE SUMMARY

(i) ABSTRACT

Studies were conducted of gradients of ascochyta blight in 1989 lentil crops. The gradients resulted from movement of inoculum into fields from infested 1988 residues in adjacent fields. Even with favorable weather for spread, movement was limited and steep gradients were maintained on the edge of the crop until harvest. Treatments to the edge of the crop to further restrict disease spread were only partially effective. As from 1986-88, plots were established at several locations to determine the epidemiological consequences of planting seed with different levels of ascochyta. The results suggest that, except in the Black Soil Zone, or in pedigreed seed production, a tolerance of 5% ascochyta would be acceptable.

(ii) SUMMARY

There were two principal objectives of this project: (a) to make a quantitative study of gradients of ascochyta blight in lentil crops planted adjacent to infested residues of 1988 lentil crops. This included making sequential measurements of the spread of disease into the crop during the growing season and investigating the effects of three possible management practices to restrict disease spread into the crop. (b) to study the consequences of planting lentil seed with different levels of ascochyta infection. This was to expand and confirm data from three preveious years' of study and provide a means of developing tolerances for seed borne ascochyta of lentil.

DISEASE GRADIENTS

Experiments were set up in four commercial crops of Laird lentil in early May. Each crop was planted adjacent to a 1988 lentil field in which ascochyta blight had occurred. Two of the crops were at Laird (1 and 2), one at North Battleford and one at Zealandia. As anticipated these locations provided a range of rainfall during the growing season; all locations enjoyed abundant moisture in May and early June, but after that time the Zealandia location was extremely dry and the North Battleford location was the wettest. Different treatments were imposed in the different crops. In all four there was a check, in which the 1989 lentil crop was contiguous with the 1988 lentil residue, and a treatment where the farmer left a strip of summerfallow (24-50 ft wide, depending on equipment) between the 1989 crop and the 1988 residues. At Laird 1, Zealandia and North Battleford there were treatments with a strip of cereal between the crop and the residues. Finally, at Laird 1 and Zealandia a treatment was included in which a strip of the crop next to the residue was sprayed several times with the fungicide chlorothalonil, starting at early flowering.

Sampling transects were staked out across the fields in each treatment in May or early June; four transects were included in each treatment. During the growing season several measures of disease severity were made at fixed distances from the 1988 residues in each transect. This allowed the progress of disease across the field to be monitored. In June the percentage of seedlings with ascochyta lesions was counted. In July and early August two measures of the percentage of foliage affected by ascochyta blight were made. Shortly before harvest plant samples were collected in burlap bags, dried and combined. If the seed from a crop showed discoloration due to ascochyta, seed grades were determined. All harvested seed samples were tested for percentage ascochyta infection by a standard agar plate method.

The results indicate that sharp disease gradients away from the 1988 residues were evident at all four locations at the seedling stage. However, at two locations they were confounded by foci of infection elsewhere in the crop; in part these were due to the presence of seed borne inoculum, as none of the growers had used completely disease-free seed. At Zealandia the dry weather virtually eliminated the disease gradient by harvest time; very low seed infection levels occurred even adjacent to the 1988 residues. At the other locations the disease spread further into the crop as the season progressed, but a steep gradient was maintained and movement was restricted. By harvest time substantial disease occurred only in the first 50 m from the edge of the crop next to the residues.

The different management treatments reduced, but did not completely prevent, spread of disease into the lentil crops from the residues. The best treatment was the cereal isolation strip, especially at North Battleford where it was 17 m wide. The failure of the cereal and summerfallow isolation strips to prevent spread was probably due to movement of plant residues into the field by wind and machinery, possibly as early as during the 1988 harvest. Wider strips might have been completely effective. The fungicide application greatly reduced infection of harvested seed in the sprayed area but did not prevent spread of disease into the field. In retrospect, fungicide application should probably have been initiated at an earlier stage of crop growth. In future work, additional treatments for reducing disease spread into lentil crops should be investigated. However, confirmation of the 1988 finding that steep disease gradients exist on the edge of crops, even at the end of the season, suggests that growers could control disease by the simple expedient of harvesting and handling the edge of the crop separately from the rest.

TOLERANCES FOR SEED-BORNE ASCOCHYTA

Replicated plots large enough to simulate field conditions were seeded on summerfallow land, or land free of lentil residues,

at Saskatoon (irrigated), Floral, Regina and Melfort. The treatments were identical at each location, i.e. five levels of seed infection with ascochyta (from 0% to 14%) in each of Laird and Eston lentil. The following data were collected: seedling emergence; disease severity on maturing plants; yield; seed quality (according to the Canada grade standards); percentage infection of harvested seed (as determined by a standard agar plate test).

Seedling emergence was not related to percentage infection of the seed planted and the incidence of ascochyta lesions on seedlings was extremely low. Nevertheless, differences in disease severity on maturing plants and in seed grade and percentage infection of harvested seed were broadly related to infection levels in the seed planted. This was especially true at Regina and Saskatoon, where better moisture conditions resulted in generally higher disease levels. Yields were not significantly different among initial seed infection levels but there was a significant difference between Eston and Laird.

The results must be judged in conjunction with those of similar experiments from 1986-1988. There was always a broad relationship between infection of planted seed and of harvested seed. Over 20 station years with a variety of conditions, there have been very few cases where a severe epidemic and discolored seed have resulted from planting seed with up to 5% infection with ascochyta. This was true even in the highly susceptible cultivar Eston. In the few exceptions (Saskatoon, 1988 and 1989 and Melfort, 1987), even treatments with 0% infection eventually resulted in considerable disease. This indicates that disease development was mainly an artefact of the experimental design, i.e. due to spread between adjacent plots. However, the exceptions also occurred only under conditions of exceptionally frequent rainfall or irrigation.

On the basis of four years' results, it is recommended that a general tolerance level of 5% ascochyta be established for lentil in Saskatchewan. The only exceptions to this would be (a) when lentil is planted in the Black Soil Zone, where normally more frequent rainfall occurs and (b) in the production of pedigreeed seed. For the pedigree classes Breeder, Select and Foundation a 0% tolerance should be established. This is partly in recognition of what low levels of seed infection occasionally lead to under moist conditions. It also recognizes the fact that in the early stages of seed multiplication it is easier to control disease because small areas and small amounts of seed are involved.

(b) TECHNICAL REPORT

ABSTRACT

Studies were conducted of gradients of ascochyta blight in 1989 lentil crops. The gradients resulted from movement of inoculum into fields from infested 1988 residues in adjacent fields. Even with favorable weather for spread, movement was limited and steep gradients were maintained on the edge of the crop until harvest. Treatments to the edge of the crop to further restrict disease spread were only partially effective. As from 1986-88, plots were at several locations to determine the epidemiological consequences of planting seed with different levels of ascochyta. The results suggest that, except in the Black Soil Zone, or in pedigreed seed production, a tolerance of 5% ascochyta would be acceptable.

BACKGROUND AND OBJECTIVES

Ascochyta blight caused by Ascochyta fabae f. sp. lentis, is a seed and stubble borne disease of lentil that can have a major economic impact on production in Saskatchewan. The main effects of the disease of importance to growers are severe seed discoloration, yield loss and delayed crop maturity. Previous research in Saskatchewan has shown that control is generally enhanced by adequate crop rotation, growing the moderately resistant cultivar Laird, using disease-free seed, applying a seed treatment fungicide or spraying the growing crop with a fungicide. However, to date no fungicides are registered in Canada either for seed treatment or foliar application. The fact that the approved methods of control are not always fully effective, or are not always used, is evident from the severe epidemics growers sometimes experience, especially when wet weather favors disease spread. Even the cultivar Laird shows a loss of resistance as the plants mature and, although yield losses are limited, severe seed discoloration and offgrading still may occur.

Our work over several years in plots showed that disease-free seed planted on clean land (ie. with no lentil residues from the previous year) would lead to a disease-free crop. However, in 1987 a number of growers experienced epidemics that appeared to contradict this finding. Consequently in 1988 we conducted a disease survey of 114 lentil crops which included analysis of samples of the seed planted. The purpose was to establish the source of inoculum in diseased crops. In fields planted adjacent to 1987 lentil residues we paid particular attention to differences in disease levels between parts of the crop close to, and distant from, the 1987 residues. We were able to show steep gradients of disease away from the 1987 residues in cases where weather conditions had been favorable for spread. This information is of considerable importance to practical management of ascochyta blight; at the very simplest it implies that in a crop with such

a steep gradient harvesting and handling different parts of the crop separately might be worthwhile. It might avoid contaminating all harvested seed from the field with heavily diseased seed from one edge.

The first objective of the present study was to make a quantitiative study of disease gradients in lentil crops planted adjacent to infested 1988 residues. This included following the spread of disease into the crop during the growing season by sequential measurements. Also included was an investigation of the effects of interposing strips of summerfallow, a cereal crop, or of fungicide-sprayed lentil on the form of the gradient. These were considered to be potential control measures a grower might use without major expense.

A second aspect of the work related to tolerances of seed-borne infection of lentil with ascochyta. A paradox for growers is that although using disease-free seed is recommended, lentil seed carying ascochyta can frequently be planted without any risk to the crop. We have sometimes planted seed with over 25% ascochyta infection, but because of dry weather have harvested completely disease-free seed. On the other hand, planting seed with very low levels of infection may sometimes lead to a major epidemic and severely discolored harvested seed, if rainfall is frequent in June and July. Despite the obvious importance of weather during the growing season, there is reason to believe from our work over the past several years that spread of ascochyta blight in a crop is usually slow enough that the final disease level reflects the initial level. This, in fact, is characteristic of rain-splash dispersed pathogens. Thus, under average conditions ascochyta blight might be controlled by regulating the level of infection in planted seed (ie. setting a maximum tolerance), and not necessarily insisting that growers use completely disease-free seed.

According to the above, a second objective of the present study was to repeat 1988 plot tests on the epidemiological consequences of planting lentil seed with different levels of ascochyta infection. The study in 1988 was supposed to be the final year of a 3-year project, but severe drought damage in the plots resulted in very limited data. In 1989, as in 1988, the tests were designed to help establish rational tolerances for seed borne ascochyta in lentil.

EXPERIMENTAL METHODS

Disease gradients.

Whereas the original intention had been to conduct a survey of about 30 commercial lentil fields in four areas of Saskatchewan to locate fields with gradients of ascochyta blight, time

constraints made this impossible. Instead, four fields of Laird lentil planted adjacent to 1988 lentil residues were located in April or May. The designation of these fields according to location was as follows: Zealandia; North Battleford, Laird-1 and Laird-2. As hoped for, the widely separated locations provided a range of rainfall during the growing season, especially after early June. The major difference was between Zealandia and the other locations; whereas good moisture conditions prevailed at all locations in May and early June, drought prevailed after this time at Zealandia.

Different treatments were imposed in the four fields, the number depending on the extent to which the farmer was willing to disrupt his normal cropping practice. In all four fields there was a check, in which the 1989 lentil crop was contiguous with the 1988 lentil residue, and a summerfallow treatment where the farmer left a strip of summerfallow between the 1989 crop and the 1988 residues. At North Battleford, Zealandia and Laird 1 there was a non-host treatment where a strip of cereal crop was planted between the lentil crop and the residues. The widths of the summerfallow and non-host treatments varied among fields according to the size of the farmer's machinery. Finally, at Zealandia and Laird 1 there was a fungicide-sprayed treatment in which a strip of the lentil crop next to the residues was sprayed during flowering with chlorothalonil at 1.7 kg ai/ha. Spraying was done twice and three times at Zealandia and Laird 1, respectively. All treatment strips in all fields were at least 80 m long. Further details of the treatments imposed and the experimental layout are given in Table 1 and Figure 1.

Table 1. Details of management strategies for ascochyta blight of lentil relative to disease spread from adjacent lentil residues investigated at three locations in Saskatchewan in 1989.

Crop Location	Position of 1988 Lentil Residues	Management Strategy Investigated	Width of Isolation and Sprayed Strips (M)
Laird 1	West	Summerfallow	8
		Non-host wheat	8
		Fungicide	9
Laird 2	East	Summerfallow	9
Zealandia	West	Summerfallow	8.5
		Non-host barley	8.5
		Fungicide	9
North Battleford	North	Non-host barley	16.5
		Summerfallow	16.5

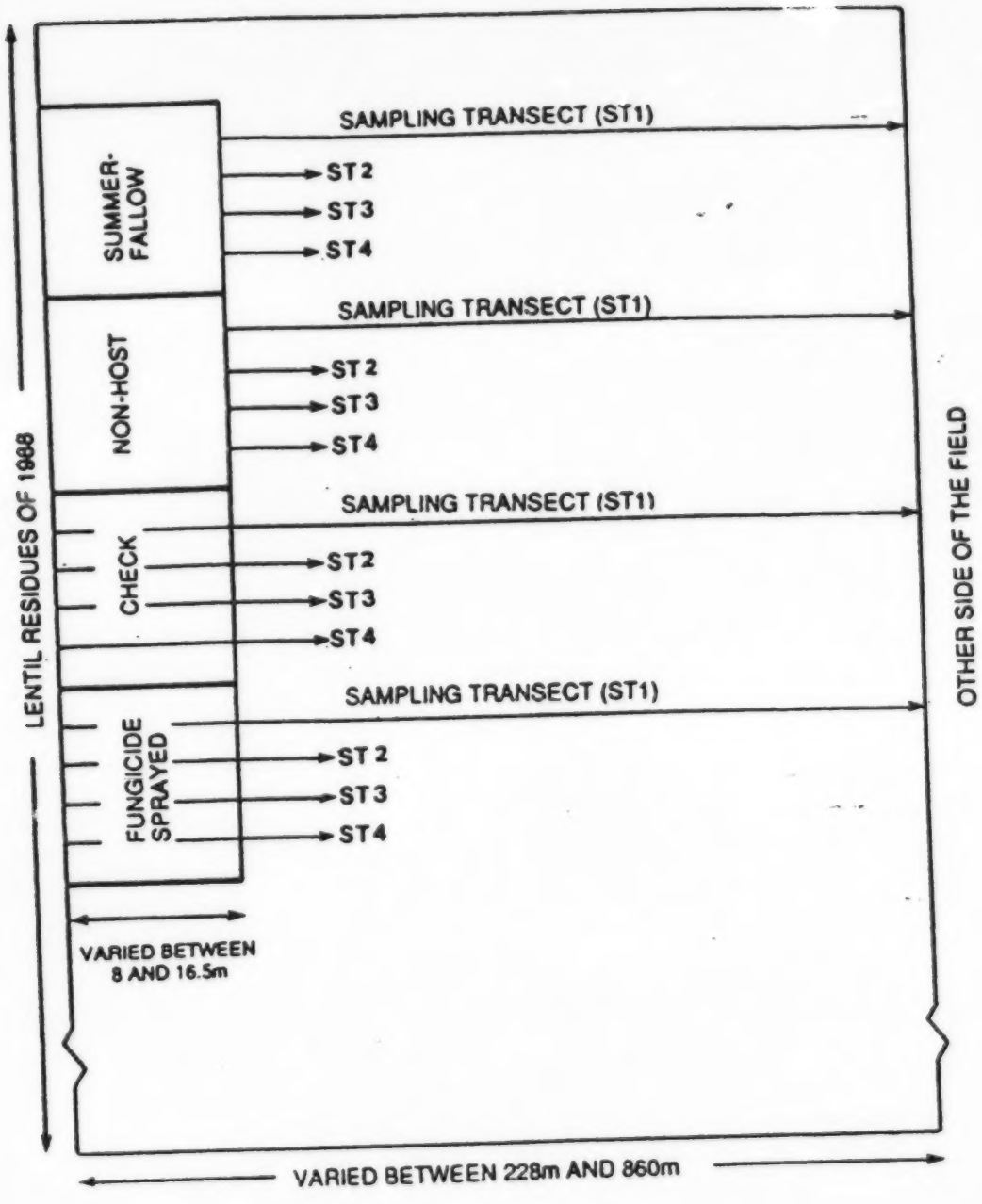

Figure 1. General experimental design used in disease gradient studies of ascochyta blight.

In May or early June sampling transects were staked out across each of the study fields. Four transects, each about 15 m from its nearest neighbour in the same treatment were established in each treatment of each crop. Thus, there were four subsamples per treatment, but no replication of the treatments in the fields. In each transect, stakes to mark sampling sites were placed at about 10 distances from the edge of the 1988 residues extending across the entire field. Most of the sampling sites were positioned close to the 1988 lentil residues since previous studies led us to expect steep disease gradients. During the growing season several variables were measured at the sampling sites. The number of seedlings emerged per m^2 was measured in early June by placing a quadrat on the ground and counting the number of seedlings in it. At the same time percentage disease incidence on the seedlings was determined by counting the number of seedlings with one or more lesions caused by ascochyta blight in the quadrat. Measurements of disease severity were made in early July and again in late July or early August by assessing the percentage of above-ground tissue affected by ascochyta blight according to the Horsfall-Barratt scale. Shortly before the farmers harvested the crops, plant samples were collected in burlap bags, dried and combined. One hundred seed samples from each site were tested for ascochyta infection by surface sterilizing for 10 min. in 0.6% NaOCl, plating on 20% V8 juice agar, incubating for 10 days at room temperature and counting the number of seeds giving rise to colonies of Ascochyta. All of the above variables were measured at all sampling sites in all treatments at all four locations except for Laird 2. At this location seedling emergence and disease incidence were not determined because of extremely low disease levels and shortage of time.

Establishment of tolerances for seed-borne ascochyta in lentil

Essentially identical plot experiments were established in May at four locations: Saskatoon (irrigated); Floral (near Saskatoon), Regina and Melfort. The experiment was a 2 x 5 factorial with 4 replicates. The main factor was the two cultivars Eston and Laird and the second factor consisted of five levels of seed infection with Ascochyta. By judicious mixing of batches of heavily infected and disease-free seed an attempt was made to achieve similar percentage infection levels in each cultivar. After mixing, samples of the five levels for each cultivar were tested by agar plating. Thus, the actual levels of seed infection achieved were as follows: Eston - 14.25%, 7.5%, 3.25%, 1.0%, and 0%. Laird - 13.25%, 7.25%, 4.50%, 3.25% and 0%. As germination was extremely poor at the Floral site, especially in Laird lentil, the plots were ploughed down and a second test planted. Because of lack of plot space only three replicates and three levels of seed infection were included.

All tests were conducted on land that had been summerfallowed in the previous year or planted to a non-host crop. Relatively large plots in which over 3000 seeds were planted were used and they were surrounded by strips of barley. There were three main reasons for this structure: (a) better simulation than in small plots of epidemiological conditions in commercial fields (b) reduction of disease spread from one treatment to another (interplot interference) by the barley, and (c) reduced chances of random error in the initial seed infection levels (treatments), especially at low infection levels.

At each location the test was arranged in a split-plot, randomized complete block design, with cultivar as the main-plot effect and ascochyta level in the seed as the sub-plot effect. Each sub-plot at Saskatoon and Melfort consisted of 16 rows 4.9 m long with 30 cm row spacing. At Floral each sub-plot consisted of 20 rows 3.7 m long with 30 cm row spacing. At Regina, each sub-plot consisted of 16 rows 4.6 m long with 22.5 cm row spacing. Each sub-plot was isolated from others by borders (between sub-plots) and pathways (between blocks and main plots) planted to barley. The borders and pathways were 1.2 m and 1.8 m wide, respectively at all locations except Melfort where the pathways were 2.4 m wide.

Date of seeding varied among locations from May 2 to May 18, except at Floral where seeding occurred on June 1. Rhizobium inoculant was added with the seed at all locations. Seeding was done at a rate of about 40 seeds/m using a small-plot tractor-drawn seeder. Periodic hand weeding ensured weed control throughout the growing season.

Emergence was determined 3.5-4.5 weeks after seeding. The number of seedlings was counted in 3 m lengths of two adjacent rows from two subsamples in each plot. Percentage disease severity on maturing plants was determined by visual inspection of entire plots. Percentage tissue diseased was rated according to the Horsfall-Barratt scale. Ratings were done twice at Saskatoon, Melfort and Floral and once at Regina.

Harvest date and procedure varied slightly among locations depending on cultivar, weather conditions when the plants were ripening and distance from Saskatoon. Two subsamples from either side of each plot were harvested. The plots were trimmed to a length of 3.0 m and four rows were hand harvested as a subsample. After cutting, the plants were bagged and forced-air dried to minimize post-harvest deterioration. Seeds were threshed with a Hege combine and mechanically cleaned. Seed yield and grade and the percentage of seeds infected by Ascochyta sp. were measured.

Seed grade was assessed according to the Canada grade standards[1] by a person unaware of the treatment distribution. Only discoloration of seed due to Ascochyta sp. was taken into consideration. The percentage of seeds infected by Ascochyta sp. was determined by plating on 20% V8 juice agar. In order to save time, one replicate block of all treatments was initially tested from each location. Subsequently decisions were made about whether it was worthwhile to do further tests and, if so, which treatments and replicates.

Analyses of variance using the SAS GLM Procedures were used to identify significant factors in the data from each separate location. Rainfall and temperature data for the various locations at which the experiments were conducted were obtained from the nearest, Official Environment Canada Meteorological Stations.

RESULTS AND DISCUSSION

Disease gradients

The year 1989 was relatively good for crop growth in most parts of Saskatchewan until July, when below normal precipitation and above normal temperatures were recorded at some locations. However, weather conditions were relatively conducive to disease at Laird and North Battleford, resulting in severe infection in some parts of the crops there. At Zealandia, hot, dry weather in the latter half of June and in July severely limited disease development.

The planted seeds at Laird 1, Laird 2 and Zealandia tested 0.75%, 0.5% and 5% ascochyta respectively. No seed sample was available for North Battleford, but the grower stated that a test had indicated that the seed contained a low level of ascochyta. Despite seed infection, at all locations gradients resulted from disease moving into the crops from 1988 lentil residues in adjacent fields. The patterns of spread were studied as disease incidence on seedlings, disease severity and final seed infection in relation to distance from the edge of the crop.

Disease incidence

At all locations except Laird 2 ascochyta blight had spread into the crop a distance of 20 m by the middle of June (Figures 2-4). The distribution of disease was not uniform. The percentage of infected plants decreased progressively away from the inoculum source except in the check at Laird 1, where an anomalous increase occurred 200 m away (Figure 2). However, this anomaly was

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[1]Grades: No. 1 = 0-2% discolored, No. 2 = 2-3.5%, Extra No. 3 = 3.5-5%, No. 3 = 3.5-10% and No. 4 (sample) > 10%.

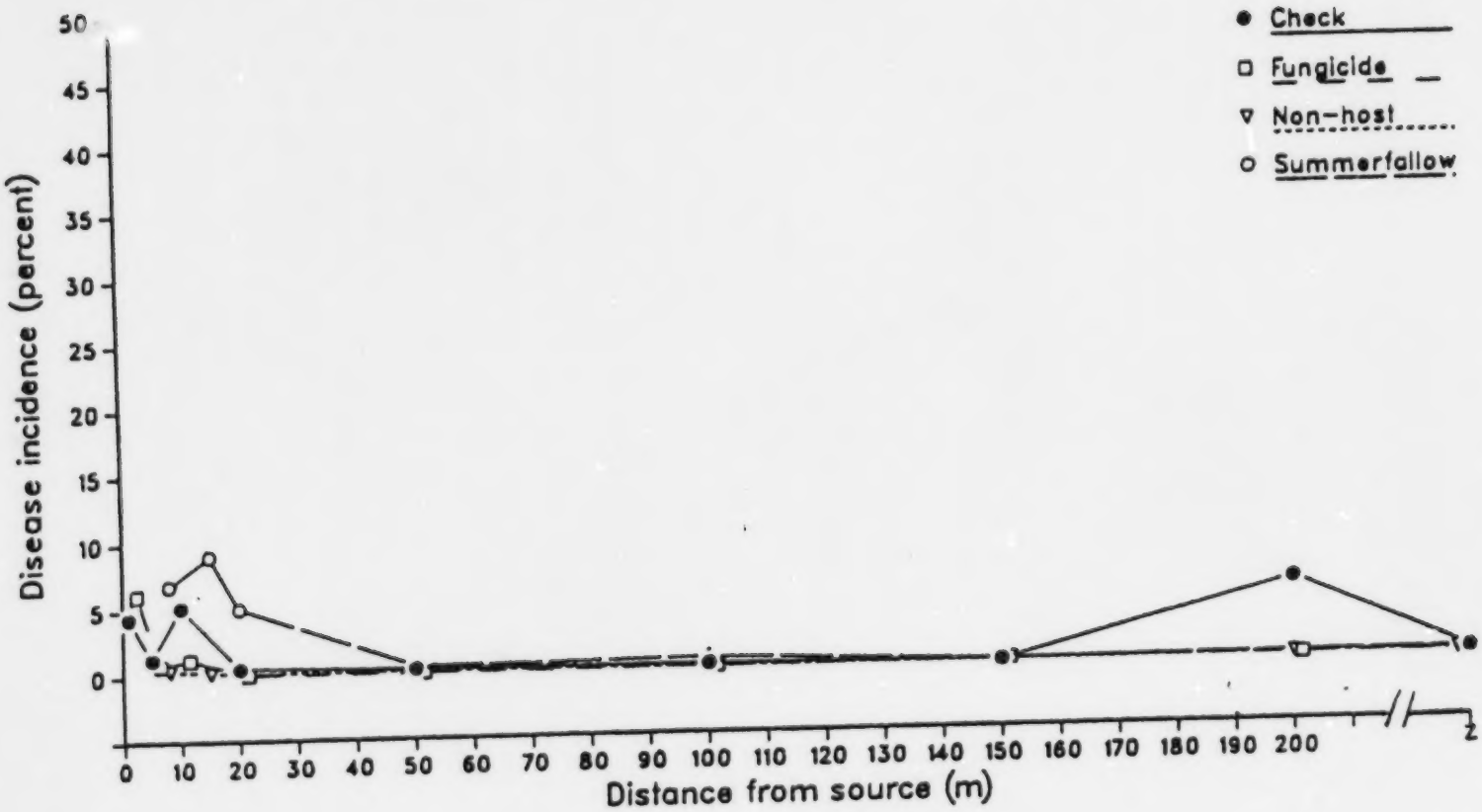

Figure 2. Percentage incidence of ascochyta blight on lentil seedlings in relation to distance from an area source of inoculum at the edge of the field in four treatments at Laird 1, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

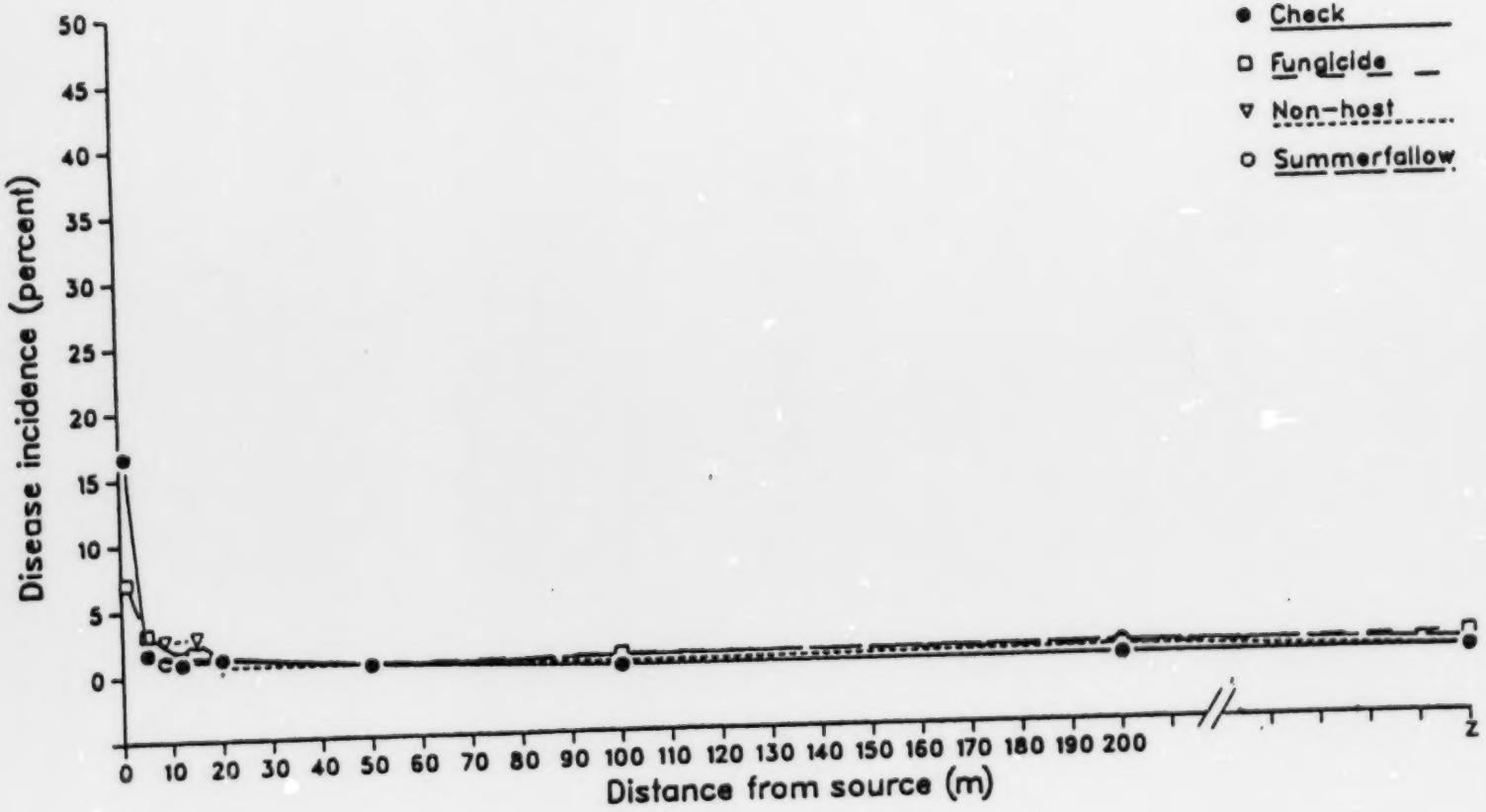

Figure 3. Percentage incidence of ascochyta blight on lentil seedlings in relation to distance from an area source of inoculum at the edge of the field in four treatments at Zealandia, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

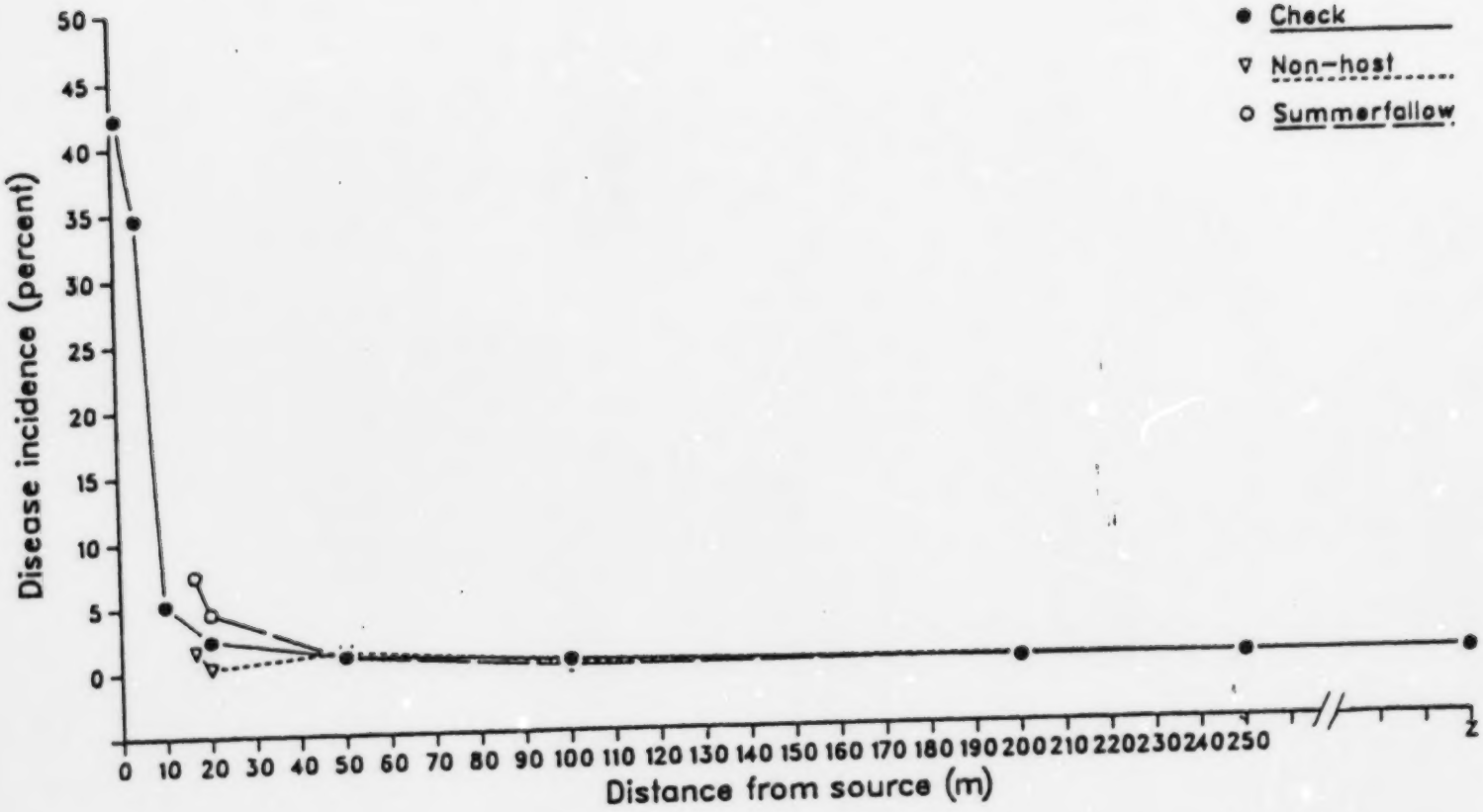

Figure 4. Percentage incidence of ascochyta blight on lentil seedlings in relation to distance from an area source of inoculum at the edge of the field in three treatments at North Battleford, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

restricted to only one sampling transect (Figure 5).

The disease incidence gradients were steep for the checks at North Battleford and Zealandia. At North Battleford, the mean incidence of seedling infection was 40.2% close to the inoculum source and only 0.5% 100 m away (Figure 4). Similar trends were evident at Laird 1 and Zealandia in the fungicide treatments (before the application of fungicide). The check at Laird 1 showed an increase in disease 10 m from the inoculum source and then a dramatic decrease. In the isolation strip treatments, the gradients were relatively flat at all locations (Figures 2-4). Despite the flatter gradients, the isolation strips had not prevented movement of disease into the crop. Among the treatments, the treatment with the non-host isolation strip had the lowest percentage of infected seedlings. Among the locations where measurements were made, the lowest disease incidence was at Laird 1 and the highest at Zealandia.

Disease severity

Disease severity varied with time and space. The ratings indicated that disease declined with increasing distance from the inoculum source. The aerial plant area affected by ascochyta blight was also different among treatments. The check values were generally higher than those of any other treatments.

In the check, disease severity varied between 1 and 8% at Laird 1 and Zealandia, 1 and 2% at Laird 2, and 1 and 14% at North Battleford on the first assessment date. At Laird 1, the disease severity increased between the first and second assessment dates while at Zealandia and North Battleford it decreased. At Laird 2, the epidemic progressed little over time and disease severity never exceeded 2.5%.

For the non-host isolation treatments, all disease severity values at Laird 1 and North Battleford were 2% or lower on the first assessment date. However, they were relatively high at Zealandia, ranging from 1% to 6%. On the second date the reverse applied because at Zealandia severity decreased while at Laird 1 and North Battleford it increased. For the summerfallow isolation treatments, disease severity was higher at North Battleford than at any other location. The values ranged between 1 and 6% and 1 and 9% at Zealandia and North Battleford respectively. At Laird 1 and Laird 2, severity values did not exceed 2% on the first assessment date but increased with time.

The first disease severity evaluation in the fungicide treatment was done before fungicide was applied. Only one application was made between the first and second assessment dates at both locations. The effect of fungicide between the two dates was slight at Laird 1. Although there was no clear cut demarcation between sprayed and non-sprayed areas of this treatment, a slight

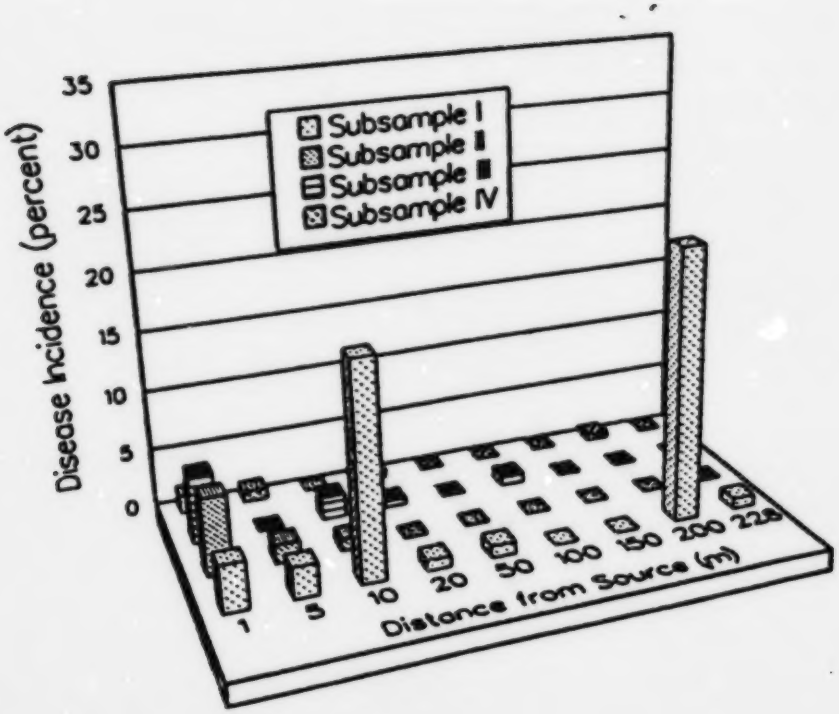

Figure 5. Disease incidence gradients for ascochyta blight of lentil in the check at Laird 1, Saskatchewan in 1989. Distance axis is not linear

increase in disease severity values was observed in the non-sprayed area. At Zealandia, there was no difference between the two dates.

Seed infection

Steep seed infection gradients were observed only for the check at North Battleford and the summerfallow isolation treatment at Laird 1. For all other treatments at all locations, the gradients were relatively flat (Figures 6-9). Moreover, only in the check at North Battleford was the gradient of seed infection a relatively smooth curve. In other treatments, fluctuations occurred along the gradients.

The frequency of ascochyta infection in the harvested seed was low at Laird 2 and Zealandia. At Laird 2 the crop was extremely weedy, especially next to the residues in the check section. It is possible that weeds may have reduced the spread of disease by acting as a wind break or by reducing the impact of raindrops on the lentil foliage. However, the possibility of a weak inoculum source cannot be ruled out, since the weather conditions during the summer were conducive for a blight epidemic. At Zealandia, the initially high disease incidence did not translate into corresponding disease severity and seed infection levels because of poor moisture conditions after early June. At Laird 1 and North Battleford the moisture conditions were favourable and this was reflected by relatively high seed infection (Figures 6-9).

Among the isolation treatments the best control of seed infection was achieved with the 16.5 m wide non-host strip at North Battleford (Figures 6-9). Seed infection levels were relatively low compared to the summerfallow strip at the same location. A similar trend was observed at Laird 1, although ascochyta infection was relatively higher. At Laird 2, the summerfallow treatment showed more disease than the check. At Zealandia there was no difference between these two treatments. Seed infection was less than 2%. Considering all four locations, the general trend of the results suggested that barriers created by a non-host crop were fairly effective in reducing disease intensity. This effect was a function of the width of the isolation strip.

For the fungicide treatment, although ascochyta infection of the seed from the unsprayed area at Laird 1 was not different from the check, the area sprayed showed low seed infection despite proximity to the inoculum source. The fungicide apparently protected the seeds and pods from further infection. At Zealandia, efficacy of the fungicide was enhanced by dry weather and consequently seed with close to zero percent infection was harvested from the sprayed area.

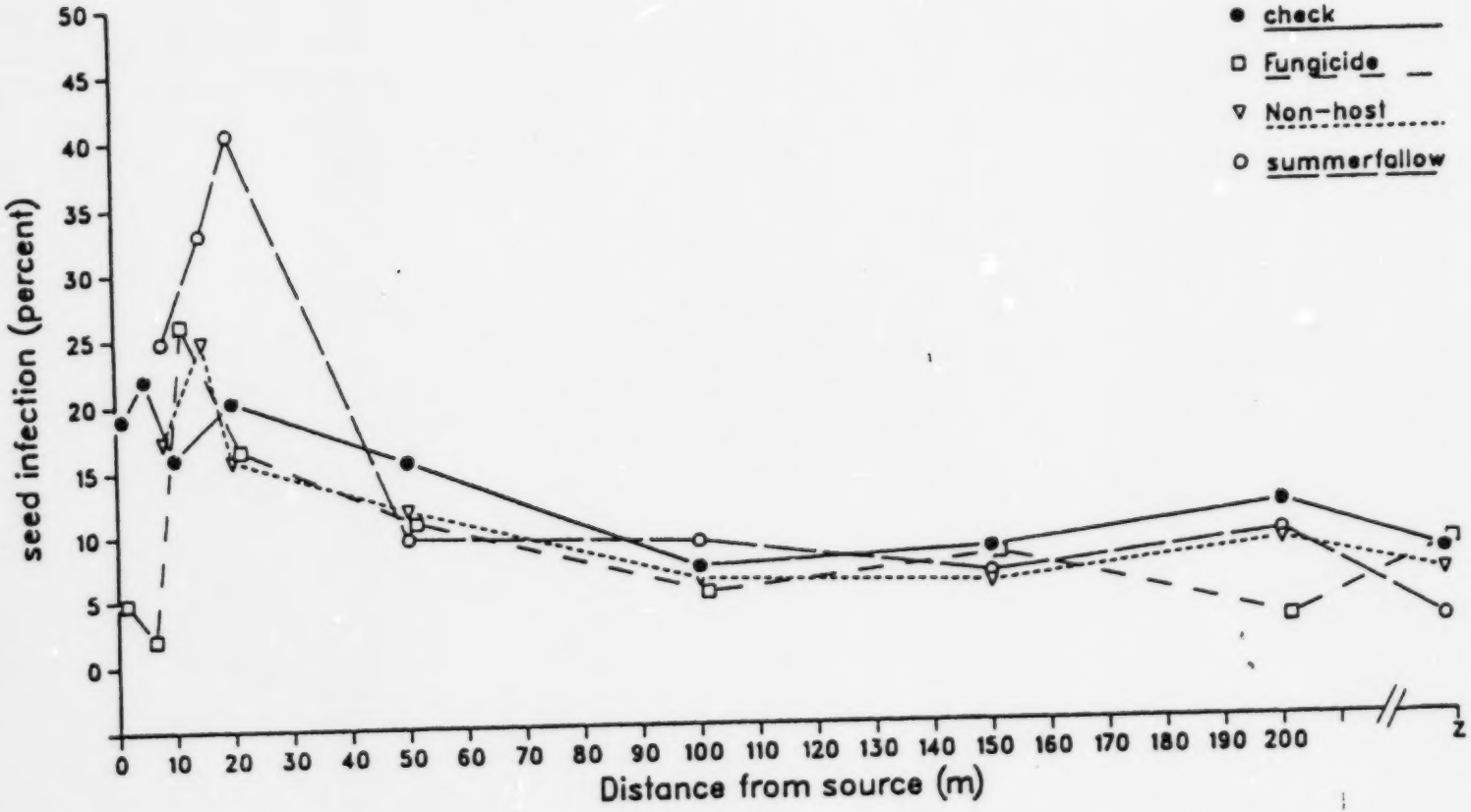

Figure 6. Percentage seed infection of ascochyta blight in relation to distance from an area source of inoculum at the edge of the field in four treatments at Laird 1, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

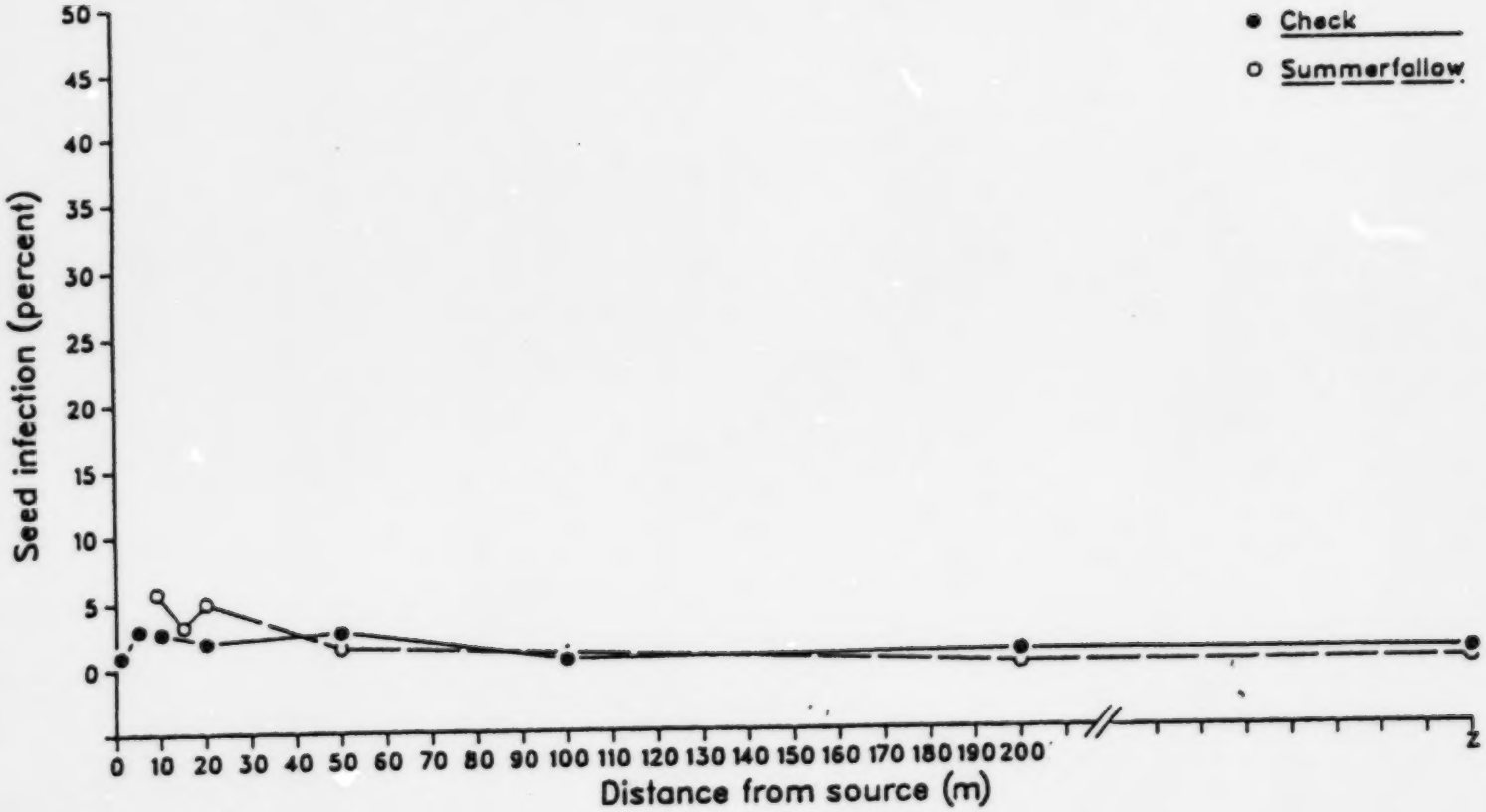

Figure 7. Percentage seed infection of ascochyta blight in relation to distance from an area source of inoculum at the edge of the field in two treatments at Laird 2, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

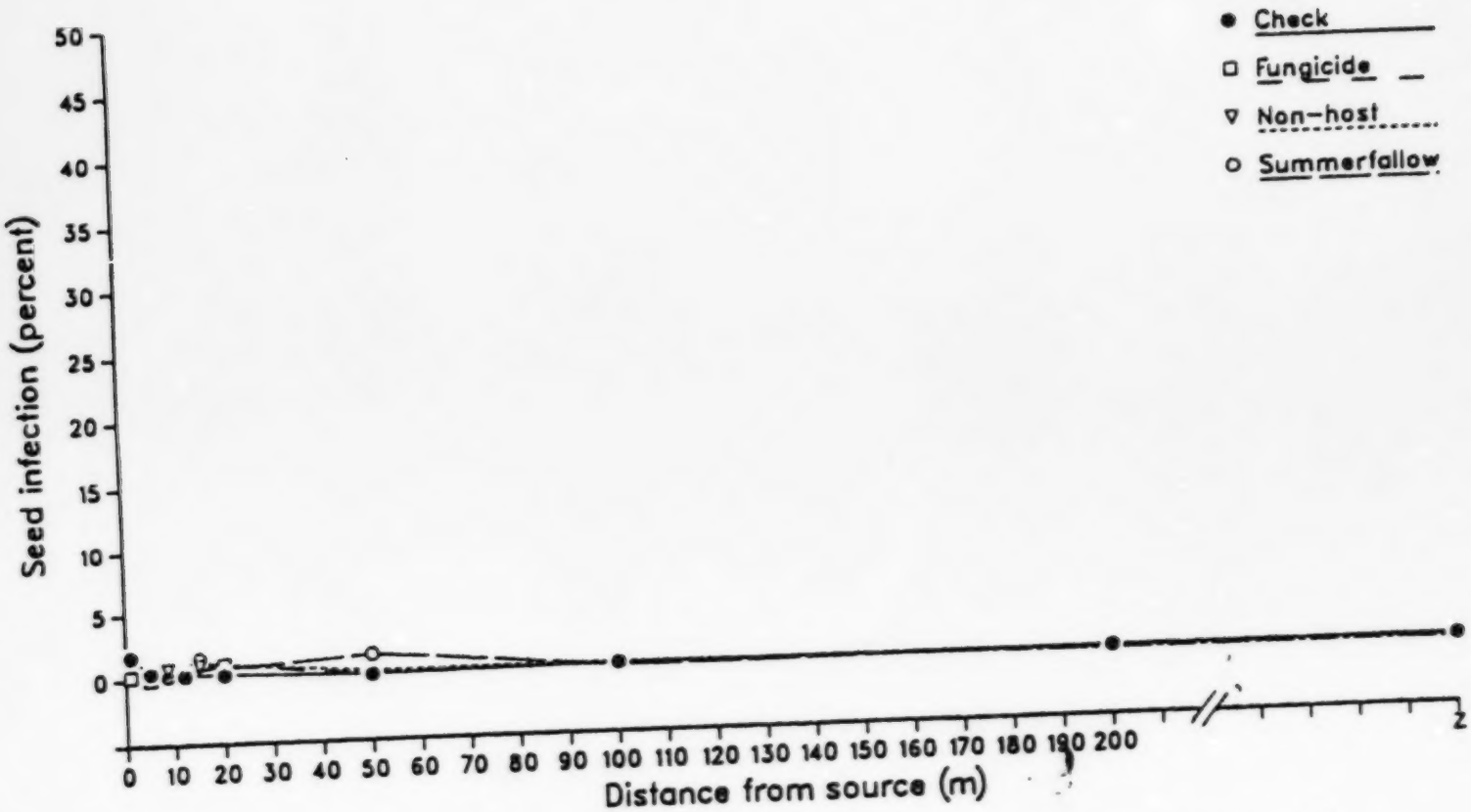

Figure 8. Percentage seed infection of ascochyta blight in relation to distance from an area source of inoculum at the edge of the field in four treatments at Zealandia, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

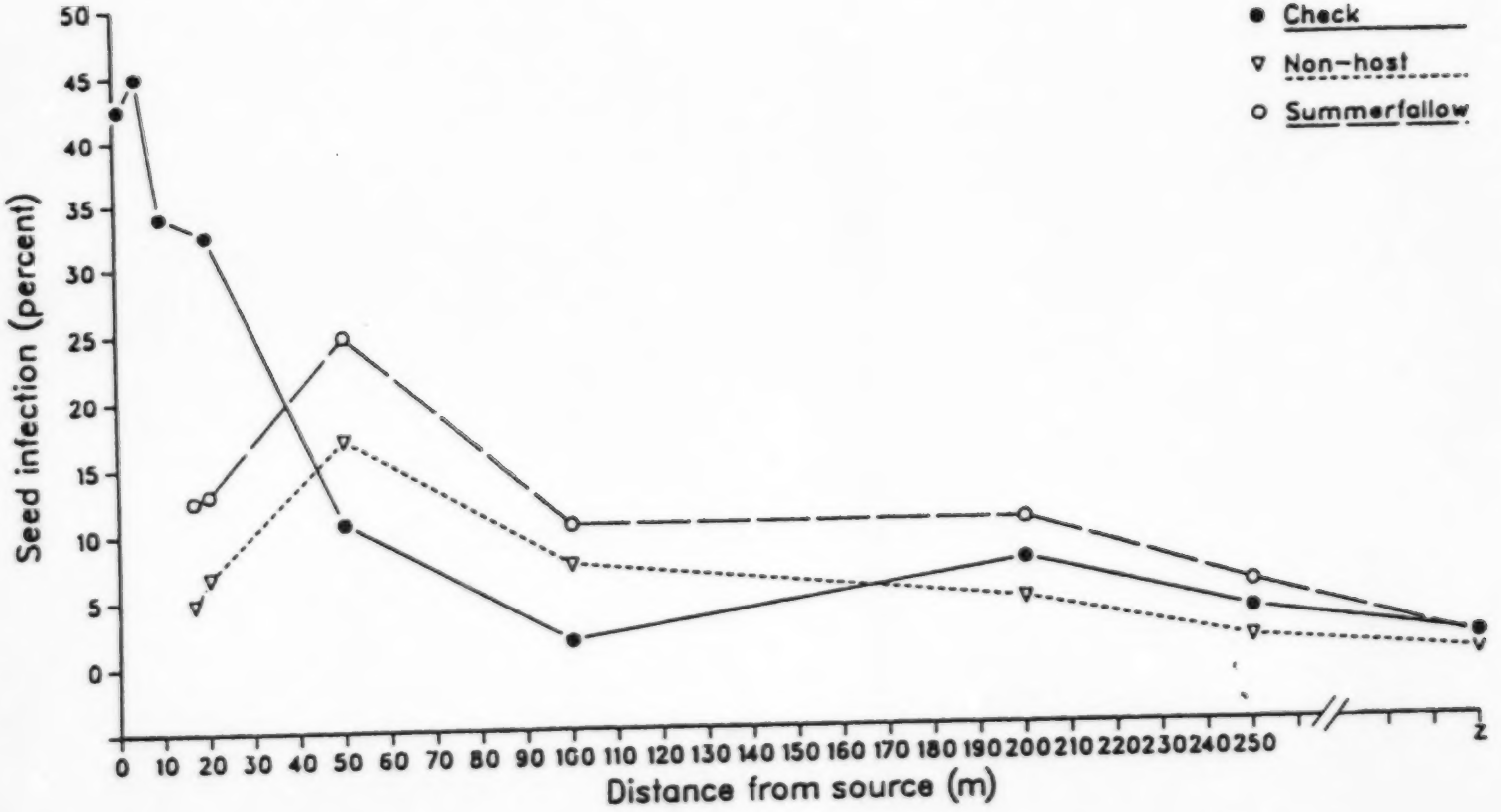

Figure 9. Percentage seed infection of ascochyta blight in relation to distance from an area source of inoculum at the edge of the field in three treatments at North Battleford, Saskatchewan in 1989. The point Z on the abscissa represents the 'other side' of the field.

Plant density

There was variation in crop density at all locations. The overall mean of plants/m^2 was 143, 106 and 83 at Laird 1, Zealandia and North Battleford respectively. At Laird 1 plant density was relatively high (182 plants/m^2) at 20 m from the source as compared to the edge of the field (109 plants/m^2). At North Battleford, in the isolation treatments, there were 110 plants/m^2 at 50 m compared to 52 plants/m^2 at the edge. A noteworthy feature was that seed infection was sometimes associated with higher plant density.

Seed grade

Grading of harvested seed was done only for Laird 1 and North Battleford. Most seed samples were graded Canada #1 and #2 at North Battleford. However, some were graded Canada #3 and Canada Sample, especially in the check. Isolation treatments had a considerable effect on seed grade at North Battleford. The mean grades at increasing distance from the source were as follows: Check - 1 m = 4, 5 m = 4, 10 m = 3.5, 20 m = 3, 50 m = 1.5, 100 m = 1.3, 200 m = 1.3 and 250 m = 1; Non-host - 16.5 m = 1.8, 20 m = 1.8, 50 m = 2.5, 100 m = 2, 200 m = 1.3 and 250 m = 1. Similar results were obtained for the summerfallow isolation strip treatment. At Laird only a few of the samples were graded Canada #3 and none was graded #4. Nonetheless a trend was evident showing improved seed grade with distance from the inoculum source.

Establishment of tolerances for seed-borne ascochyta in lentil

Favourable conditions resulted in good emergence and stand establishment at most locations. However, conditions were hot and dry in the latter part of the season and this restricted disease development. Relative ripeness of the plants at harvest varied among locations and between cultivars. Eston plots were harvested earlier than Laird at all locations.

Seedling emergence

Seedling emergence varied among locations, but the differences were not tested statistically (Table 2). The differences probably related to soil conditions and date of emergence counts. Differences between the two cultivars were significant at all locations. Since Laird is large seeded and prone to mechanical injury it is probably relatively susceptible to soil-borne seed rotting fungi.

Significant differences in emergence among treatments occurred only at Floral where emergence increased with increasing levels of initial seed infection (Table 2). Clearly, infection incidence is not a reliable indicator of germinability or seed quality. The

TABLE 2. Emergence of seedlings of two cultivars of lentil in relation to initial seed infection levels with A. fabae f. sp. lentis at four locations in Saskatchewan in 1989.

Treatment		Emergence (seedlings/m row)[a]			
Cultivar	Level of ascochyta infection in seed planted (%)	Saskatoon** (irrigated)	Melfort*	Regina**	Floral*
Laird	0	50	35	26	11
	3.3	21	30	24	-
	4.5	22	31	23	12
	7.3	23	31	23	-
	13.3	22	30	25	14
Eston	0	33	31	25	24
	1	33	36	26	-
	3.3	35	36	27	28
	10.8	32	34	25	-
	14.3	34	32	26	31

[a] Based on two sub-samples in each of four replicates, except at Floral where it was based on two sub-samples in each of three replicates.

*, ** Emergence was significantly different between cultivars at p=0.05, p=0.01 respectively.

potential for variation due to soil factors should also be recognized.

Seedling infection

Seedling infection directly reflects seed to seedling transmission of pathogens. In both cultivars, the incidence of seedlings with ascochyta lesions was either extremely low or zero, even in treatments with the highest level of initial seed infection. Therefore, quantitative assessments were not done, as there was no possibility of showing statistically significant differences. However, the finding is consistent with results in previous years and important, in itself, relative to the transmission frequency of Ascochyta from infected seed to seedlings. It is possible that the precise location of the inoculum in the seed is involved. Previous studies have suggested that the majority of inoculum is restricted to the seed coat or cotyledons; these remain below ground during germination and inoculum there may not have time to spread to the emerging shoot. Consequently the transmission frequency is low.

Disease severity on maturing plants

Disease severity was low on both dates, fluctuating from one to four percent tissue diseased at all locations except Saskatoon (Table 3). Analyses of variance of the disease ratings showed no significant differences between the two cultivars or among levels of seed infection. It was not surprising that there were no differences among plots that eventually produced seed with less than 2% infection. However, at Saskatoon, where more seed infection eventually occurred, a trend was apparent on the second date (Table 3); Eston plots had more disease than Laird plots and there was also an indication of a positive relationship between initial seed infection and disease severity.

Yield, seed grade and seed infection

Yield differed among locations and was significantly greater in the cultivar Eston than in Laird (Table 4). However, in no case was yield correlated with level of seed infection.

Laird graded uniformly Canada #1 at all locations and Eston graded Canada #1 at all locations except Saskatoon. At Saskatoon, although there was no significant difference among the levels of seed infection, some samples in the high treatment levels graded Canada #2 and #3.

At Saskatoon, significant differences in level of infection in the harvested seed occurred between cultivars, among levels of

TABLE 3. Disease severity on maturing plants of two cultivars of lentil in relation to initial seed infection levels with A. fabae f. sp. lentis at four locations in Saskatchewan in 1989.

Treatment		Mean disease ratings (%)[a]						
Cultivar	Level of ascochyta infection in seed planted (%)	Saskatoon (irrigated)		Melfort		Regina	Floral[b]	
		June 19	July 19	July 6	July 21	June 30	June 29	July 18
Laird	0	2	1	1	2	1	1	1
	3.3	2	2	2	2	1	-	-
	4.5	4	2	1	2	3	1	1
	7.3	1	2	1	2	2	-	-
	13.3	2	1	1	2	2	1	2
Eston	0	1	2	1	1	2	2	1
	2	1	4	1	1	1	-	-
	3.3	1	3	2	2	3	2	1
	10.8	2	6	2	1	2	-	-
	14.1	4	8	2	2	4	1	1

[a] Mean of four replicates except where otherwise indicated.
[b] Mean of three replicates.

TABLE 4. Yield of two cultivars of lentil in relation to initial seed infection levels with A. fabae f. sp. lentis at four locations in Saskatchewan in 1989.

Cultivar	Treatment: Level of ascochyta infection in seed Planted (%)	Yield (kg x 10^3/hectare)[a]: Saskatoon** (irrigated)	Melfort*	Regina*	Floral[b]*
Laird	0	1.8	1.6	2.1	0.6
	3.3	1.6	1.7	2.3	-
	4.5	1.7	1.8	2.2	0.6
	7.3	1.8	1.6	2.5	-
	13.3	1.7	1.5	2.2	0.7
Eston	0	2.6[b]	1.8	2.8	1.4
	1	2.5	2.0	2.3	-
	3.3	2.4	1.7	2.1	1.1
	10.8	2.4	1.8	2.5	-
	14.1	2.4[b]	1.9	2.4	1.1

[a] Based on two subsamples in each of 4 replicates except where otherwise indicated.

[b] Based on two subsamples in each of 3 replicates.

*,**Yield was significantly different between the two cultivars at P=0.05 and P=0.01 respectively.

initial seed infection and in their interaction. In Eston, the level of infection in the harvested seed ranged as high as 16% (Table 5). Although conditions were relatively unfavourable for ascochyta blight in the latter part of the growing season, irrigation clearly aided in the spread of the disease. However, in cv. Laird disease development was restricted (Table 5). After a separate analysis of variance of data from Eston plots at Saskatoon, single degree of freedom contrasts showed that the contrast, "Eston 1-3 vs Eston 4-5" was significant at $p = 0.05$. Thus, in Eston there was a positive correlation between percentage infection in harvested seed and initial seed.

At Saskatoon even in plots in which seed with 0% ascochyta was planted, seed with more than 6% infection was harvested. However, this probably reflects the spread of inoculum from neighbouring plots. Despite the use of relatively large plots and guard rows of barley to reduce interplot interference, when conditions are favourable disease spread occurs from one plot to another. Such interference may increase the variability of data and may lead to erroneous conclusions concerning the magnitude of treatment effects or relative value of different treatments. The disease is either overestimated or underestimated compared to what would apply to a farmer's field.

At Melfort, Regina and Floral, seed infection was less than 2% in all Eston and Laird treatments (Table 5). There were no significant differences between the cultivars nor among the levels of seed infection. The results suggested that although the weather affects the development of an epidemic as the crop matures, final disease is partly a function of the initial level of disease. Slight variation in seed infection among locations other than Saskatoon was presumably because of differences in local weather conditions.

CONCLUSIONS AND IMPACT

Disease gradients

This study confirmed preliminary results from 1988 showing that steep gradients of disease severity and infection of harvested seed may exist in lentil crops planted adjacent to lentil residues of the previous year. These gradients relate to movement of inoculum of *Ascochyta fabae* f. sp. *lentis* into the crop from infested residues. Even under conditions highly favorable for disease spread, as applied at two locations in 1989, steep gradients are maintained until the end of the growing season. This is because the majority of disease transmission is by rain-splash of spores and movement is restricted. In 1989 little disease occurred beyond 50 m from the edges of crops adjacent to 1988 lentil residues. Consequently, whereas seed heavily infected with ascochyta may be harvested from the edge of such crops, relatively high quality seed will be found in the rest of the field. A simple expedient for disease control for a farmer who recognizes this

TABLE 5. Infection in harvested seed of two cultivars of lentil in relation to initial seed infection levels with A. fabae f. sp. lentis at four locations in Saskatchewan in 1989.

Treatment		% Ascochyta infection in harvested seed[a]			
Cultivar	Level of ascochyta infection in seed planted (%)	Saskatoon (irrigated)	Melfort	Regina	Floral
Laird	0	0.3	0.3	0.6	0.3
	1	0.4	-[b]	-	-
	3.3	1.0	0.5	0.9	0.3
	10.8	0.1	-	-	-
	14.1	0.3	1.0	0.4	0.1
Eston	0	6.8	0	0	0
	3.3	6.4	-	-	-
	4.5	7.6	0.9	0.3	0.1
	7.3	15.8	1.8	1.0	-
	13.3	14.7	1.1	1.0	0.3

[a] Based on 2 subsamples in each of 4 replicates except, Floral where it was based on two subsamples in each of three replicates.

[b] Not determined.

problem is to harvest the edge of the field separately from the remainder. This would avoid contaminating the entire production from the field with diseased seed.

Another goal of the present study was to investigate other disease management strategies that might reduce disease severity and extent of disease spread. Since spores are dispersed by rain-splash, isolation of the crop by either leaving a strip fallow or interposing a non-host barrier seemed appropriate for reducing or delaying initial infection. The spraying of the heavily infected area on the edge of the crop adjacent to the residues was also done to reduce the movement of inoculum into the crop.

Chlorothalonil is a protectant fungicide which reduces disease severity and seed infection by affecting spore germination. Disease control was evident at Laird 1 and Zealandia in the areas sprayed. However, the main objective of spraying, to retard the movement of inoculum into the crop was not achieved. Considering the time of first application, it is probable that disease had already spread beyond the protected range. Perhaps more effective control of the spread of inoculum could have been achieved by an earlier first spray and this simple strategy should be further investigated in future studies.

Both the summerfallow and non-host isolation treatments might have helped to reduce the pathogen population by interrupting the infection chain from the inoculum source. However, summerfallow strips were not completely effective at any location in reducing disease spread and epidemic development. Non-host strips were relatively more effective. An isolation distance of 16.5 m with a barrier of non-host crop at North Battleford gave the best results.

The failure of the summerfallow and non-host isolation strips to completely prevent disease spread into the lentil crop probably resulted partly from the fact that some alternatives to disease spread by rain-splash exist and partly from the experimental design. Because the source of inoculum was lentil residues in farmers' fields there was a potential, especially during the spring and previous autumn, for wind movement of infected residues into the study field. Similarly, cultivating and harvesting machinery could cause movement of residues. Indeed, early in the growing season when measurements of disease incidence were made, residues of the 1988 crop were often visible on the soil surface in the first 10 m of the gradient. This actually makes the maintenance of disease gradients on the edge of crops throughout the growing season more remarkable. It is possible that, without movement of residues in this way, steeper and more restricted gradients would have been maintained on the edge of the field. This possibility should be investigated in future studies. Under better controlled conditions in experimental plots where movement of infected residues could be eliminated, the horizontal spread of ascochyta blight due strictly to rain-splash could be determined. It would also be possible to compare disease spread in cultivars with

different levels of resistance and use this information to identify components of resistance to the disease. This would assist plant breeders in developing new cultivars.

Since, in farmers' fields, wind- and machinery-movement of lentil residues into adjacent fields cannot be eliminated, practical disease control measures must take this into account. The evidence to date suggests that an isolation distance of at least 20 m from the nearest lentil residues is necessary to protect a lentil crop from horizontal ingress of ascochyta blight. However, the best control could probably be achieved by integration of chemical treatments, not currently registered, with cultural practices such as isolation.

Establishment of tolerances for seed-borne ascochyta

The results of this study must be judged in conjunction with results of similar experiments obtained over the previous three years. In these studies a possible inoculum tolerance level was studied in relation to three important factors. First, the effect of different levels of seed infection was observed in relation to disease development. Second, the role of local weather in spread and subsequent infection of the new seed was examined by conducting the same experiment at several locations. Third, in three of the four years host susceptibility was tested by using two cultivars of different disease reaction.

A general consideration of the epidemics at each location in 1989 shows that the percentage ascochyta infection of new seed was low even in the highly susceptible cultivar Eston. Apparently seed to seedling transmission and rate of disease spread were low. The low frequency of seed to seedling transmission was consistent with earlier studies and probably related to relatively high soil temperatures, low intensity of infection of the seed and location of inoculum in components of the seed which remain below ground during germination. No correlation between seedling disease and initial seed infection was observed, partly because of extremely low levels of seedling disease. However, there was a broad positive relationship between initial seed infection and percentage infection of the harvested seed. This indicates that some differences in seedling disease among experimental treatments must have occurred, even if they were not detectable. Such differences would eventually be reflected in infection of seed harvested from the plots, given low rates of disease spread.

The results from 1986-89 suggest that epidemics of ascochyta blight can be managed by setting seed infection tolerances, and thereby regulating the incidence of seedling disease. For example, over 20 station years it was extremely rare for treatments with below 5% initial seed infection to give > 1% infection of the harvested seed, even in the highly susceptible cultivar Eston. When > 1% infection did occur, there were mitigating circumstances that would not apply in a farmer's field, such as interplot interference among treatments. This suggests that there is minimal

risk if seed with up to 5% infection is planted. However, such a conclusion might be applicable only in certain areas or under certain climatic conditions.

Temperature and moisture are important in the development of ascochyta blight. In 1989, adequate rainfall for crop growth and disease development occurred in May at all locations. Poor moisture conditions at Melfort in late June and July and at Floral in July limited disease. Low percentage seed infection occurred at the end of the growing season. At Regina, although total rainfall was above average during the growing season, relatively high disease severity in July did not translate into high seed infection. This could be attributed to the hot dry weather that prevailed from the latter part of July until harvest. Although there were four episodes of rainfall, only one exceeded 4 mm. Moreover, the average afternoon high during the period was 30 C. High temperatures reduce periods of wetness after rain and thereby restrict spread of the fungus. Despite what happened at the Regina location, some seed infection developed in the susceptible cultivar Eston at Saskatoon, where irrigation facilities were available. However, both disease severity and seed infection were moderately high only in the two treatments with the highest initial seed infection.

The above discussion points to the importance of moisture in July when plants are maturing. The lack of adequate moisture for disease spread in late July 1989 was reflected in the harvested seed; except for a few samples at Saskatoon, all seed graded Canada #1. On the other hand, frequent showers in July 1987 resulted in severe epidemics and seed discoloration in cv. Eston at Melfort. Consequently an inoculum tolerance level would have to depend partly on the average weather conditions of the area in which the crop will be grown.

The two cultivars used over the four years of this study are different in their susceptibility. The cv. Eston is highly susceptible whereas cv. Laird is moderately resistant. This difference was apparent in 1989 at Saskatoon where mean seed infection for all treatments was 0.4% in Laird and 10.3% in Eston. This might suggest that an inoculum tolerance level for highly susceptible cultivars should be different from that of moderately resistant cultivars. However, it should be borne in mind that although Laird has good resistance to the foliar phase of the disease, it becomes more susceptible at the late podding stage. Furthermore, relative days to maturity of the cultivars cannot be ignored. In 1988, despite unfavourable conditions for disease spread the mean frequency of seed infection in all treatments was higher in Laird than in Eston, partly because of their difference in maturity and, therefore, harvest dates.

Notwithstanding the importance of weather, under average conditions the levels of ascochyta in the seed appeared to be the main determinant of the severity of epidemics. Even with favorable periods for disease spread during the summer, average disease

progress during the season was not rapid enough to cause serious loss, except at Melfort in 1987. Consequently, for seed intended for commercial production, a tolerance level for ascochyta of 5% is recommended for both Laird and Eston for most areas of Saskatchewan. Up to this level little disease developed in either cultivar at all locations and harvested seed tested < 1% infection. The reason for setting the same level for both cultivars is to take account of maturity differences. This inoculum tolerance level would be beneficial to growers who may be able to use seed with a low level of ascochyta infection and avoid purchasing costly disease-free seed.

As implied above, tolerance levels for seed may not be effective in controlling ascochyta blight in unusual weather conditions. In such situations spraying a fungicide might be useful. However, no fungicide is yet registered in Canada for use on lentil. Consequently, in regions which normally have frequent rainfall during the growing season such as in the Black Soil Zone, the use of seed which has tested 0% or trace of ascochyta is recommended.

Pedigreed seed classes, such as Breeder, Select and Foundation are principally for multiplication. Because of what may occasionally happen under moist conditions these should be subjected to a 0% tolerance for ascochyta. At the earliest stages in seed multiplication it is easier to control disease when small areas and small amounts of seed are involved. Moreover, when seed is not destined for human consumption the use of unregistered chemicals to facilitate the production of disease-free seed might be an acceptable practice.

(c) PAPERS AND TALKS PRESENTED RELEVANT IN WHOLE OR PART TO THIS GRANT

Bedi S. 1990. Sources of inoculum and management of Ascochyta fabae f. sp. lentis on lentil. M.Sc. thesis, Univ. Saskatchewan, 140 pp.

Bedi S. and R.A.A. Morrall. 1990. Ascochyta blight in lentil crops and seed samples in Saskatchewan in 1988. Can. Plant Dis. Survey 70: (in press).

Morrall R.A.A. 1990. Studies of lentil and rapeseed diseases in Saskatchewan, Canada. Seminar presented at National Agricultural Research Centre, Islamabad, Pakistan, 16/04/90.

Morrall, R.A.A. 1990. Lentil diseases in Canada. Seminar presented at ICARDA, Aleppo, Syria, 22/04/90.

Morrall R.A.A. and S. Bedi. 1990. Effects of planting infected seed on epidemics of ascochyta blight of lentil. Paper to be presented at joint meeting of American and Canadian Phytopathological Society, Grand Rapids, Michigan, Aug. 5-9, 1990.

(d) EXPENDITURES

Previously submitted by University Business Office.

(e) PERSONNEL INVOLVED AND TIME COMMITMENT

R.A.A. Morrall (leader) - 15%
S. Bedi (graduate student) - 100%
B. Cavers (technician) - 30% (9 months)
W. Horkoff (summer student) - 20% (4 months)
J. Melin (summer student) - 20% (4 months)
J. Downing (summer student) - 20% (4 months)
R. Beaulé (summer student) - 25% (3 months)

(f) EQUIPMENT PURCHASED - None

(g) CONFIDENTIALITY AND OWNERSHIP - Not applicable

(h) NEW TECHNOLOGIES FOR DEMONSTRATION PROJECTS

(i) Isolation of lentil crops from the previous year's residues and incidence of ascochyta blight.

(ii) Separate harvesting of portions of lentil crops adjacent to and distant from the previous year's lentil residues.